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ABSTRACT
In Chagar Hutang, Redang Island, *Dorylus laevigatus* and *Pheidologeton affinis* were the dominant predatory ant species of the green turtle nests, and it was hypothesized that they were competitors to each other. Both species consisted of polymorphic workers, and conducted mass raiding upon turtle nests. As a result of the observation of foraging behavior of ant species in 2004 by using food traps, *D. laevigatus* (a subterranean species) shared the bait with some terrestrial ant species in the early stage of the experiment except *P. affinis*. However, *P. affinis* was a terrestrial species and established satellite nests in the traps to occupy the bait. Traps placed in the habitat of *Anoplolepis gracilipes* were immediately occupied by them during whole experimental period and other terrestrial ant species were not found in the traps. *Anoplolepis gracilipes* seemed to be the strongest competitor among the terrestrial ant species in Chagar Hutang, which might result in reduction of the population number of *P. affinis* with the existence of *A. gracilipes*. As a result, *D. laevigatus* became a major predator upon turtle nests, which might have caused the high rate of predation incidences in this area in 2004. The elimination of *A. gracilipes* may reduce predation incidences upon turtle nests by *D. laevigatus*.

KEYWORDS: *Dorylus laevigatus*, *Pheidologeton affinis*, *Anoplolepis gracilipes*, predation, green turtle, Redang Island

INTRODUCTION

In Peninsular Malaysia, the highest concentration of green turtle (*Chelonia mydas*) nesting occurs on Redang Island off the coastline of Terengganu. Long-term monitoring of nesting activities and *in situ* egg incubation has been carried out in Chagar Hutang, the major nesting beach in Redang Island since 1993 by the Sea Turtle Research Unit (SEATRU) of Kolej University Sains dan Teknologi Malaysia (KUSTEM, which name was later changed to Universiti Malaysia Terengganu; UMT.). Approximately 200 to 600 nestings per year incubated *in situ* have been counted, which were exposed to threat of predation by water monitors *Varanus salvator* (Chan and Liew, 1995), two kinds of ghost crabs *Ocypode* sp. (John, 1998), ant species (Morita, 2006), maggots, Elaterid beetle larvae (Morita, 2006). From June to October 2004 and April to October 2005 during the nesting seasons of turtles in Chagar Hutang, 30 ant species were collected. Among them, five ant species were identified as predators upon green turtle nests, viz. *Dorylus laevigatus*, *Pheidologeton affinis*, *Hypoponera* sp., *Paratrechina* sp., and *Monomorium* sp. (Morita *et al*., pending publishing a). In these years, predation incidences by ant species have been increasing (Chan, pers. comm.). The objective of this study is to investigate the mechanism of increasing predation incidences by ant species by observing their foraging behaviors. The result of this study must be the first step to establish a countermeasure for protecting green turtles' nests from ant predations.

METHODS

Research site

The study was conducted at Chagar Hutang beach (5^{o} 48.35' N, 103^{o} 00.50' E), located in the northernmost part of Redang Island, which is about 22.5 km from the mainland of Terengganu. The beach is about 350 m long and backed by hills with undisturbed tropical rain forest and is accessible only by boat. Sector number plates (1 to 35) were set on the vegetation border at 10-meter intervals from the east to the west by SEATRU. The beach is divided into three areas by two streams that run at Sectors 11/12 and Sectors 32/33 (Fig.1). *Anoplolepis gracilipes* inhabited the eastern area from Sectors 1 to 11, while *Dorylus laevigatus* and *Pheidologeton affinis* inhabited all over the beach (Morita, 2006). Underbrush in the vegetation from Sectors 1 to 11 is thin, while most of the ground in the vegetation of other sectors were covered by thick underbrush (Morita, pers. obs.).

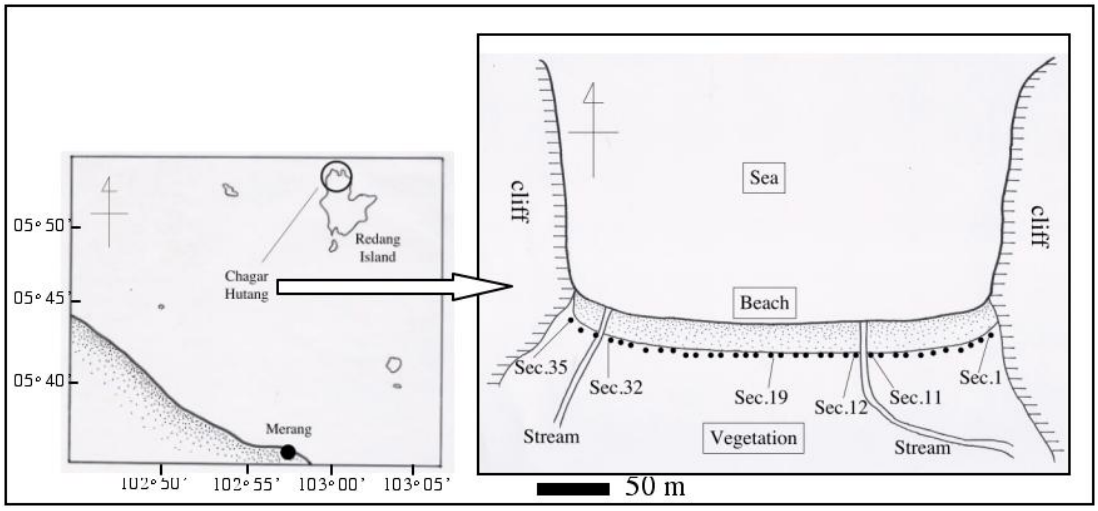

Fig. 1. Location of Redang Island (left) and Chagar Hutang, the study site (right). Redang Island is located off the coast of Terengganu. Chagar Hutang beach is on the northernmost part of the island and is 350 m long, which is divided into 35 sectors.

Food traps

A food trap experiment was conducted from 20 to 26 September 2004 to determine the food preference and distribution of ant species by using a bait of palm oil from the lipid group, syrup from the carbohydrate group, and dried fish and boiled eggs from the protein group. Especially, as *D. laevigatus* is a subterranean ant species, it is impossible to monitor through visual observation from ground surface. To detect this ant species, the palm oil was chosen for the bait, as Weissflog *et al*. (2000) found out that *D. laevigatus* was successfully attracted to palm oil.

Traps were made from recycled 500 ml plastic mineral water bottles (approximately 6 cm in diameter and 20 cm of height). The traps were modified from the bait trap proposed by Berghoff *et al* (2002). The bottles were perforated with 5 mm diameter holes so that major workers of *D. laevigatus* can pass through easily. The interval of each hole was approximately 2 cm. The top of the bottles was cut off. Each trap was covered by coral rubble collected from the beach to avoid disturbance by hermit crabs after burying into ground. Palm oil traps were filled with sand, while other traps were set like pitfall traps (Fig. 2).

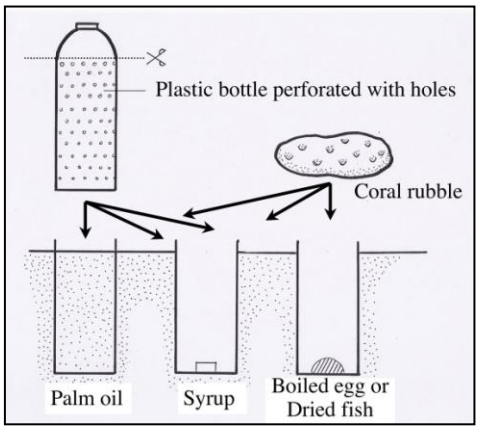

Fig. 2. Food Traps. The bottles were perforated with 5 mm diameter holes. The top of the bottles was cut off. Each trap was covered by pieces of coral rubble to avoid disturbance by hermit crabs after burying into ground. Palm oil traps were filled with sand, while other traps were set like pitfall traps.

Food traps were set along the vegetation border at eight sectors, viz. Sectors 4, 6, 8, 10, 14, 16, 22, and 23. These stations were chosen because predation incidences by *D. laevigatus* occurred previously from June to September in 2004. That suggested the network of *D. laevigatus* had been established, and it might be easy to detect them by traps. Three kinds of the bait, viz. syrup, dried fish, and palm oil, were chosen for the traps at the stations of Sectors 4, 8, 14, and 22, while boiled eggs, dried fish, and palm oil was chosen for the bait at the station of Sectors 6, 10, 16, and 23. All traps were buried approximately 12 cm deep into the ground. Palm oil bait traps were filled with sand and 10 ml of palm oil was poured from the surface. Syrup was poured into small containers

(approximately 5 ml) and placed on the bottom of the traps. Approximately 5 ml of syrup was poured directly to the bottom of the traps to soak into the soil through the holes. Ten pieces of small dried fish were placed directly on the bottom of traps. Half a boiled egg was cut into pieces and placed directly on the bottom of the traps. After setting the bait, traps were covered by coral rubble to avoid disturbance by hermit crabs (Fig. 2). Syrup, dried fish, and boiled eggs were replenished when they were consumed.

The traps were observed twice a day at around 13:00 and 21:00. The trapped ants were immediately identified. The number of ants in the traps was counted and placed in four-frequency classes (1-10, 11-100, 101-1000, and >1001 individuals). Palm oil bait traps were carefully picked up from the ground so as not to disturb subterranean ant species. Any subterranean ant species in the pits of the traps and around the trap bottles were counted. The traps were carefully buried back to the original positions. The experiment was not repeated after 26 September, because providing food to *D. laevigatus* might encourage it to establish a dense network around food trap areas, which is very near to nesting sites of green turtles.

Distribution of three ant species from the Sectors 1 to 11 in 2005

At the end of the experiment by using a chemical insecticide called Presto® (active ingredient of 0.01% Fipronil), distribution of three kinds of ant species were determined, viz. *D. laevigatus*, *P. affinis*, and *A. gracilipes* in the vegetation and on the vegetation border from Sectors 1 to 11. Line transects were set from each sector plate from Sectors 1 to 11 perpendicularly into the vegetation until the edge of the stream or cliff. Stations were set at 10 m intervals. The area was divided by the transect 6 into two, viz. the treated area (Sectors 1 to 6) and the untreated area (Sectors 6 to11).

The distribution of *D. laevigatus* and *P. affinis* was investigated in the Presto® experiment area by palm oil traps from 26 September to 15 October 2005 to determine whether the elimination of *A. gracilipes* resulted in the return of *D. laevigatus* to its original niche. The palm oil bait traps were set at each station in the same way as mentioned above. Traps were observed once a day during daytime. In this experiment, the existence of both species at the traps was recorded.

The distribution of *A. gracilipes* was also investigated at all the stations in the same area by using a quadrat (1 m × 1 m) on 16 September 2005 to evaluate the effect of the Presto® treatment. Number of *A. gracilipes* found in the quadrat at each station was roughly counted and categorized in four-frequency classes (1-10, 11-100, 101-1000, and >1001 individuals).

RESULTS

Results of the food trap experiments are shown in Fig. 3 and 4. *Dorylus laevigatus* was trapped in the habitat of *A. gracilipes*. It was attracted to palm oil and boiled eggs. It could share the bait with other terrestrial ant species. Although predation incidences upon turtle nests by this species occurred at Sectors 10, 14, 16, 22, and 23, *D. laevigatus* could not be trapped there.

Pheidologeton affinis was trapped mostly in the area without *A. gracilipes*. It was attracted to all the bait prepared. It carried sand grains in the trap bottles to make dense networks and completely occupied the bait. However, it did not stay at the traps for whole experimental period. At Sector 14, *P. affinis* was replaced from *Paratrechina* sp. At Sector 23, *P. affinis* was replaced from *Monomorium* sp. and replaced by *Monomorium* sp. later again.

Anoplolepis gracilipes was trapped at Sectors 4, 6, 8, and 10. It was attracted to all the bait prepared, especially syrup. Syrup bait traps were completely occupied and other terrestrial ant species could not approach them.

Monomorium floricola was trapped from most of the sectors without *P. affinis*. It was attracted to palm oil. Due to its body length (less than 2 mm), *M. floricola* could not approach the traps when the bait was occupied by other ant species.

Monomorium sp. was trapped from most of the sectors without *Paratrechina* sp. It was not attracted to syrup.

Paratrechina sp. was trapped mostly at Sectors 14, 16, and 22 where *A. gracilipes* did not inhabit. It was attracted to all the bait prepared except boiled eggs.

Camponotus sp. and *Odontoponera* sp. were solitary foragers. They were not trapped in the habitat of *A. gracilipes*.

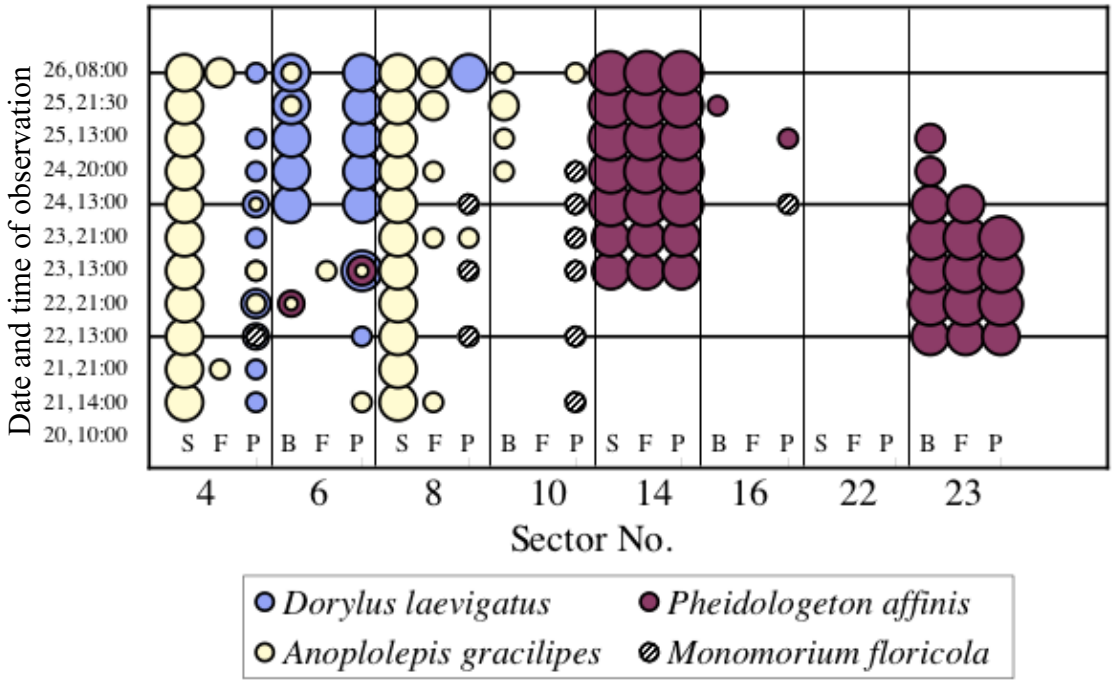

Fig. 3. A frequency level and a distribution of Dorylus laevigatus, Pheidologeton affinis, Anoplolepis gracilipes, and Monomorium floricola trapped in Chagar Hutang from 20 to 26 September 2004. A frequency level is ranging from 1 to 4, viz. Level 1: 1-10 individuals, Level 2: 11-100, Level 3: 101-1000, and Level 4:> 1000 or satellite structure, which were indicated by a size of bubbles. S, F, P, and B indicate syrup, dried fish, palm oil, and boiled eggs, respectively.

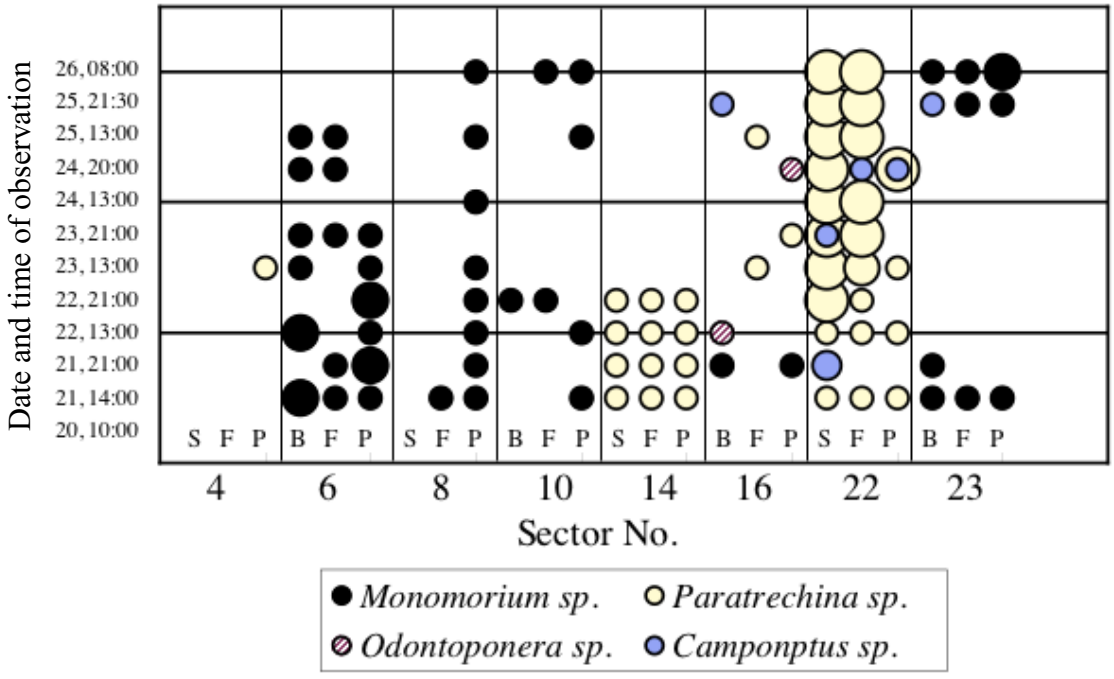

Fig. 4. A frequency level and a distribution of Camponotus sp., Odontoponera sp., Paratrechina sp. and Monomorium sp. trapped in Chagar Hutang from 20 to 26 September 2004.

Numbers of terrestrial ant species at each bait trap were compared between the habitat of *A. gracilipes* and the areas without *A. gracilipes*. The averages of species number in both areas were 1.25 and 2.42 species, respectively (Table 1). Fewer terrestrial ant species were trapped in the habitat of *A. gracilipes* (Friedman test, P = 0.0064).

Table 1: Numbers of terrestrial ant species except *Anoplolepis gracilipes* trapped in the habitat of *A. gracilipes* (Sectors 4 to 10) and the sectors without *A. gracilipes* (Sectors 14 to 23). S, F, P, and B stand for syrup, dried fish, palm oil, and boiled eggs, respectively.

Sector 4			Sector 6			Sector 8			Sector 10			**Average**
S	F	P	B	F	P	S	F	P	B	F	P	
0	0	2	3	1	2	0	1	2	1	1	2	**1.25**
Sector 14			Sector 16			Sector 22			Sector 23			**Average**
S	F	P	B	F	P	S	F	P	B	F	P	
2	2	2	4	1	5	2	2	2	3	2	2	**2.42**

The distribution of *A. gracilipes* and two predatory ants from Sectors 1 to 6 in 2005 is shown in Fig.5. Similar to the result in Fig.3, the distribution of *A. gracilipes* and *P. affinis* in the untreated area of the chemical from Sectors 1 to 6 did not overlap (G Test, P = 0.012) except three stations.

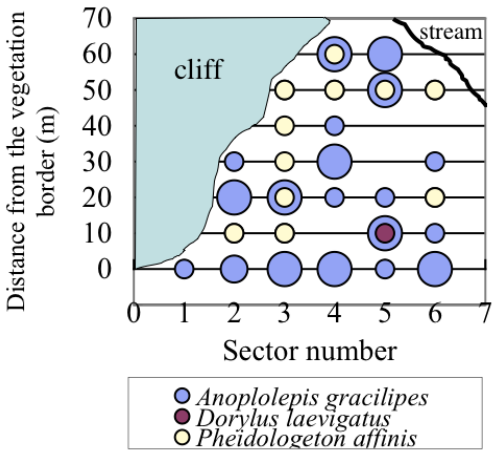

Fig. 5. Distribution of *Anoplolepis gracilipes* and predatory ant species upon turtle nests in the untreated area of the chemical experiment from Sectors 1 to 6 in 2005. *Dorylus laevigatus* and *Pheidologeton affinis* were detected by palm oil traps from 26 September to 15 October. *Anoplolepis gracilipes* was counted in a quadrat (1 m x 1 m) on 16 September and its numbers were placed into four levels, viz. Level 1: 1-10 individuals, Level 2: 11-100, and Level 3: 101-1000, which were indicated by a size of bubbles.

DISCUSSION

The result of the observation showed fewer number of trapped terrestrial ant species in the habitat of *A. gracilipes*, which suggested that *A. gracilipes* might be a strong competitor among them. Lake and O'Dowd (1991) (cited in Abbott *et al*., 2005) reported that *A. gracilipes* had changed the ecosystem and degraded natural forests, while the status of *A. gracilipes* in Chagar Hutang is not known, yet. As *A. gracilipes* and *P. affinis* are distributed separately as shown in Fig.5, there might be a likelihood that other terrestrial ant species would also face against the threat of competition upon food resources with *A. gracilipes*, if it formed supercolonies (O'Dowd, 2006). As it is not known whether *A. gracilipes* is a native species in Malaysia or not (Abbott *et al*., 2005; O'Dowd, 2006) and no observation of ant species on Redang Island has been conducted, the trend of population number of this species is unknown. However, based on the results of this observation, the existence of *A. gracilipes* in Chagar Hutang seemed to give an impact on other terrestrial ant species. That may suggest necessity of the monitoring on *A. gracilipes*, continuously.

Predation incidences by *D. laevigatus* and *P. affinis* upon green turtle nests had been observed. Based on the preliminary observation of ant species in Chagar Hutang in 2004, the rate of predation incidences by *D. laevigatus* upon green turtle nests at the habitat of *A. gracilipes* (Sec.1 to 11) was higher than that at the other beach sectors (Morita, 2006). Berghoff *et al*. (2003) observed the fighting of *D. laevigatus* and *P. affinis* in the bait traps. If there might be competition between *D. laevigatus* and *P. affinis* upon green turtle nests, *D. laevigatus* could occupy green turtle nests without the existence of *P. affinis*. Therefore, since the results of this study showed *P. affinis* could not be seen when *A. gracilipes* existed (Fig. 3, 5), the predation incidences upon green turtle nests by *D. laevigatus* might increase in the habitat of *A. gracilipes*. As *P. affinis* has both terrestrial and subterranean foraging behaviors (Berghoff *et al*., 2003), the tunnels dug by *P. affinis* from the ground surface to the turtle nests directly might block the ways of *D. laevigatus* to the turtle nests, which resulted in mitigation of predation incidences by *D. laevigatus* upon them. Well-balanced competition between *D. laevigatus* and *P. affinis* might mitigate the predation incidences. However, expansion of habitat and increasing of population number of *A. gracilipes* seemed to change the ecosystem, and reduction of habitat and decline of population numbers of *P. affinis* might cause the increase of predation incidences by *D. laevigatus* upon turtle nests. From the view of the turtle conservation activities

in Chagar Hutang, there may be a need to control the population number of *A. gracilipes* so as not to increase too much, based on the continuous monitoring activities of *A. gracilipes*. Morita (2006 and pending printing b) tried a novel method to control *A. gracilipes* selectively by using chemical bait Presto® and bamboo traps, which still needs to be improved but would be a clue to solve this matter. At the same time, grasping the relationship between *A. gracilipes* and other terrestrial ant species in detail is a further study for the turtle conservation.

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